PAUL SCHERRER INSTITUT

ELECTRO OPTICAL BEAM DIAGNOSTICS SYSTEM AND ITS CONTROL AT PSI

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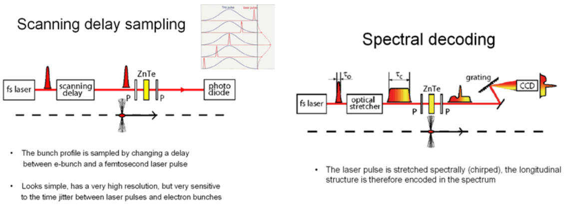
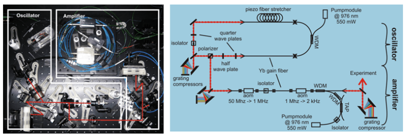
EO Highlights

Electro Optical (EO) techniques are very promising non-invasive methods for measuring extremely short (in a sub-picosecond range) electron bunches. A prototype of an EO Bunch Length Monitoring System (BLMS) for the future SwissFEL facility is created at the Paul Scherrer Institute (PSI). The core of this system is an advanced fiber laser unit with pulse generating, phase locking and synchronization electronics. The system is integrated into the EPICS based PSI controls, which significantly simplifies its operations.

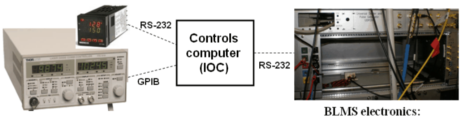


EO methods mostly used at PSI



The PSI fiber laser unit: 50 MHz oscillator and 1 MHz amplifier

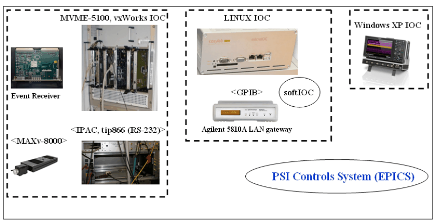
Main Bunch Length Monitoring System (BLMS) Components

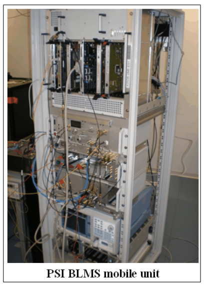


Laser stabilization elements

BLMS electronics:
Laser Synchronization Unit,
Universal Divider and Pulse Generator

BLMS Controls Hardware and Software





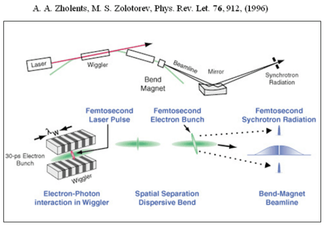
PSI BLMS mobile unit

PSI BLMS Setup

The first BLMS at the PSI was built as a mobile unit, which allowed it to be operational at two critical SLS locations: the diagnostics sections at the end of the injector and the FEMTO beam slicing facility.

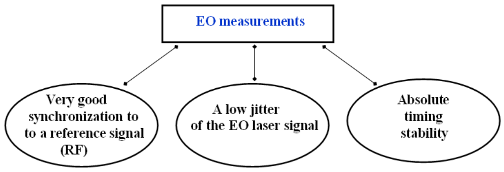
Most of BLMS parameters presented in this paper are specific for the FEMTO facility but can easily be adjusted to fit the SwissFEL case.

A. A. Zholents, M. S. Zolotorev, Phys. Rev. Lett. 76, 912, (1996)



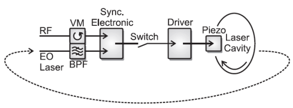
Beam slicing method

PSI BLMS Operations

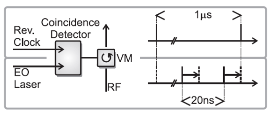


Key signals for EO diagnostics (FEMTO):
RF – 500 MHz; EO fiber laser oscillator – 50 MHz; SLS revolution clock – 1 MHz;
FEMTO slicing trigger – 2 KHz; SLS linac trigger – 3 Hz.
The revolution clock is synchronous to the revolution of a particular bunch in the SLS storage ring and the FEMTO slicing trigger is used for measurements of the sliced bunches.

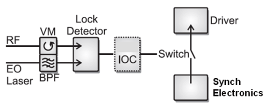
BLMS Synchronization at Work



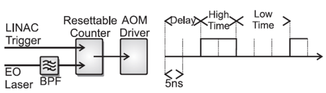
The 10-th harmonic of the EO laser repetition rate is generated by a bandpass filter (BPF) and is compared to the RF, which can be shifted in time by a vector modulator (VM). The VM shifts the phase with a resolution of 212 steps per revolution (360°). At the RF repetition rate of 500 MHz this leads to a minimal step width of about 488 fs. Two signals are compared by the synchronization electronics, generating a correction signal. The switch between the electronics and the driver is remotely controlled in order to interrupt the PLL in case of any required interlock conditions or simply to switch the synchronization on or off. A piezoelectric device finally corrects the cavity length. The repetition rate of the laser serves as a feedback signal and is closing the loop.



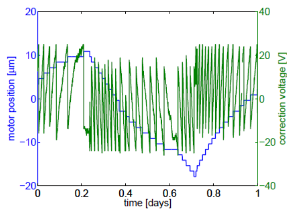
In the second step, a reproducible starting point has to be found. This is done by the coincidence detector, which compares the repetition rates of the EO laser and revolution clock. As long as the signals are not synchronous the coincidence detector control software shifts the EO laser pulse in time by rotating the phase of the RF until the overlap is found. The accuracy of this method is in the order of ±5 ps, which allows one to find such an overlap very quickly.



In case of any malfunctions of the synchronization system, interlock signals have to be generated in order to interrupt the PLL and protect the piezoelectric fiber stretcher. It is done by the lock detector controls software. As soon as the frequency difference between the RF and the 10-th harmonic of the EO laser repetition rate exceeds 1 Hz the output of the lock detector switches from logic high to low disconnecting the PLL link between the synchronization electronics and the piezo driver.



Between the oscillator and the amplifier the repetition rate is reduced to 1 MHz by an Acousto Optic Modulator (AOM). To be synchronous with the laser, this pulse picker is triggered by the repetition rate of the EO laser. The BPF generates a sinusoidal signal at 200 MHz, which is connected to the clock of a resettable counter. The counter is reset by the 3 Hz SLS linac trigger. The output is controlled in terms of a one-time delay, a high and a low time. As the device is counting with 200 MHz, these parameters can be adjusted in 5 nanosecond (ns) steps.



Besides handling interlocks the control software ensures that if the piezo voltage exceeds a certain threshold then the required correction is done by one of free space mirrors.

The left picture shows a typical behaviour of the piezoelectric stretcher (green line) and the mirror stepper motor (blue line), which is routinely provided by the controls software.

The EO BLMS at the PSI has been in operations for more than one year. The system is fully integrated into the EPICS controls, which significantly simplifies all its functions. Bunch length measurement results obtained at the SLS show that the performance of the BLMS is absolutely adequate to its main task for the SwissFEL. Some additional work is required though, mostly for dealing with signal jitters in sampling procedures.